Optical Cause of TIRS Ghosting Effect

Landsat Science Team meeting

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People who actually did the work

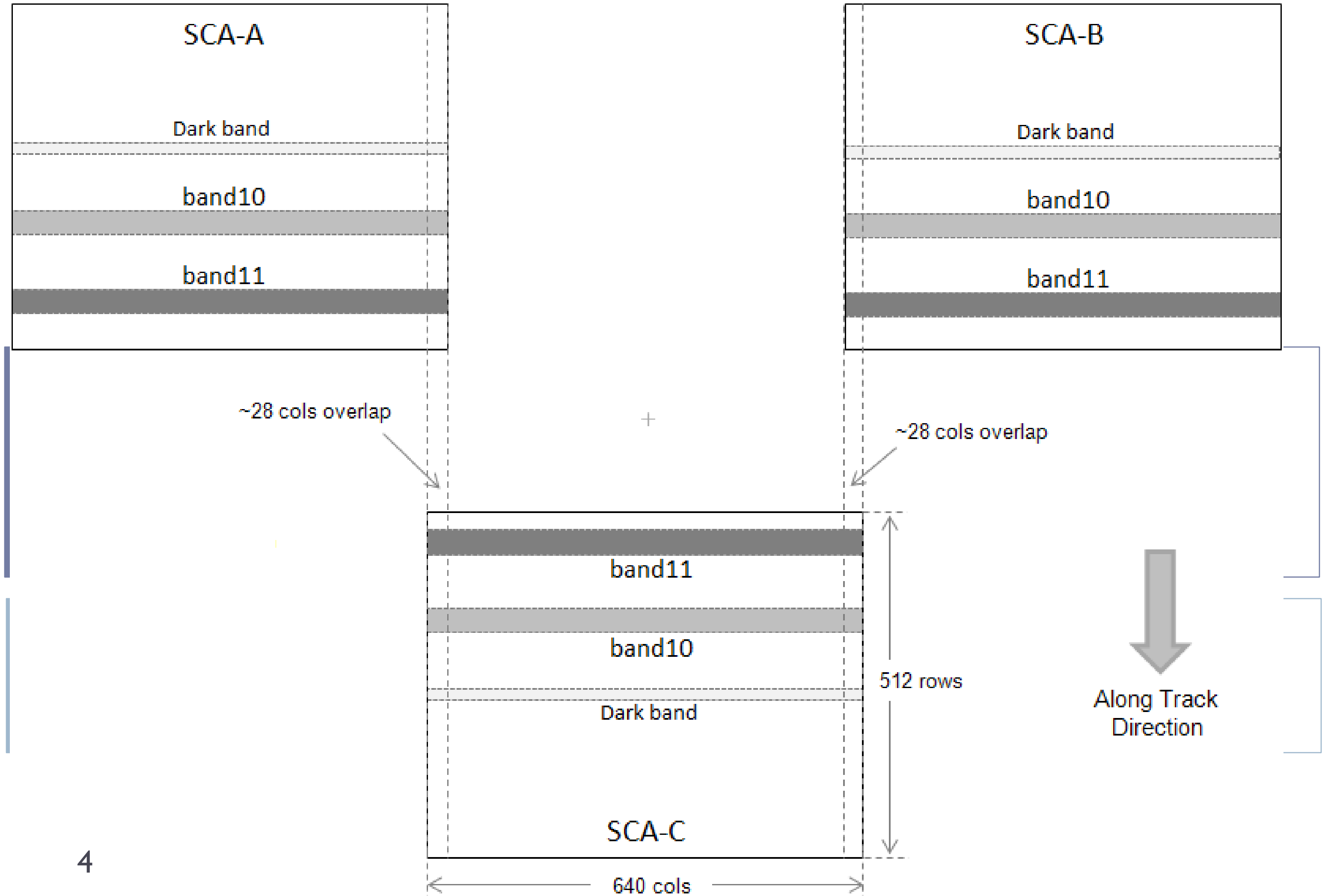
- Matt Bolcar - GSFC Code 551
- Eric Mentzell - GSFC Code 551
- Scott Rohrbach - GSFC Code 551
- Mike Hersh - GSFC Code 543 / Swales and Assoc.
- Matt Montanaro - RIT

Summary of Stray Light Problem

- Using ground Calibration, on-orbit measured LandSat-8 TIRS radiances are greater that those derived from vicarious calibration sites
  - Primarily water temperature sensing buoy sites
  - Offset changes during seasons as surrounding area warms and cools
  - Offset differs between day and night
- Lunar scans made with Moon out of the Field-of-View (FOV) show scattering effect of a few percent (more for 12 micron band than for 10.9 micron band)
  - Offset in TIRS on-orbit radiances consistent with this level of out of FOV scattering
  - Scattering arises from a ~5 degree annulus ~20 degree from the center ray of the TIRS focal plane
- Detailed modeling of TIRS optical system has reproduced observed lunar scattering observations
  - Analysis using optical model results to correct TIRS data shows promising results
- Following charts explain source of scattering, testing done to verify model and outline a simple modification that removes it

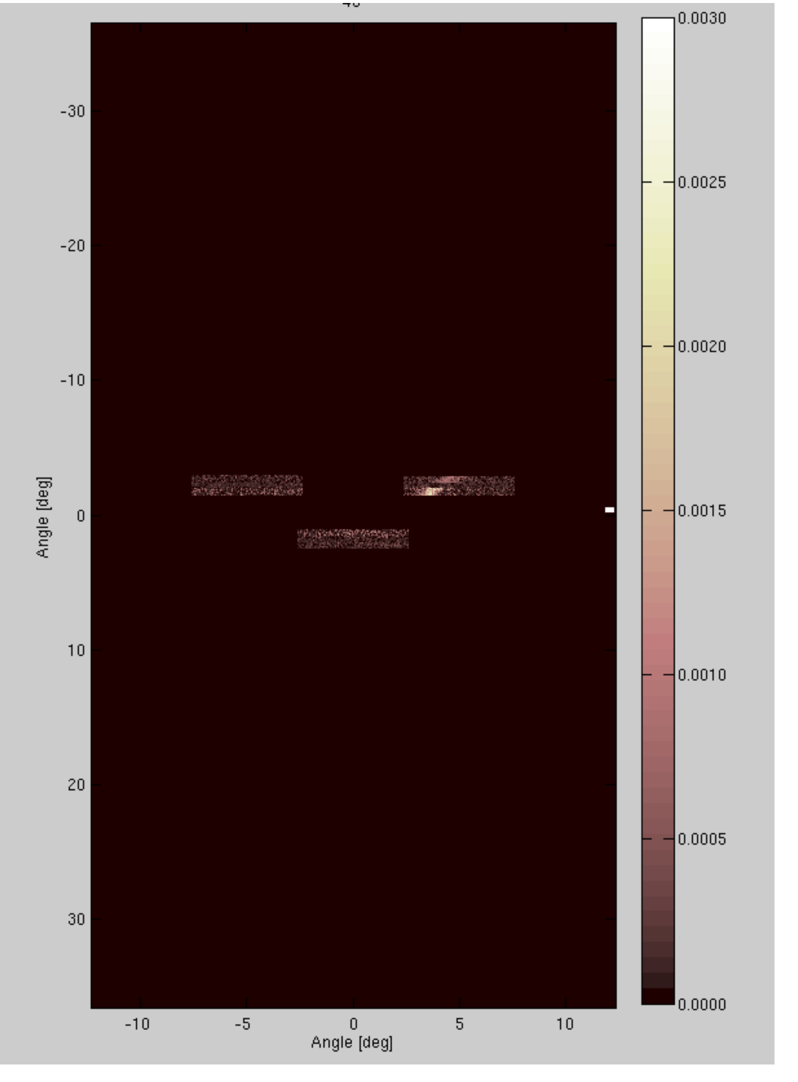
Focal Plane Layout

- Spectral filters over certain regions produce the two spectral channels; rest of array is masked.
- For normal ops: 2 rows from each of the three regions on each array are sent to the ground.
- Final image product contains combined image data from the three arrays stitched together.



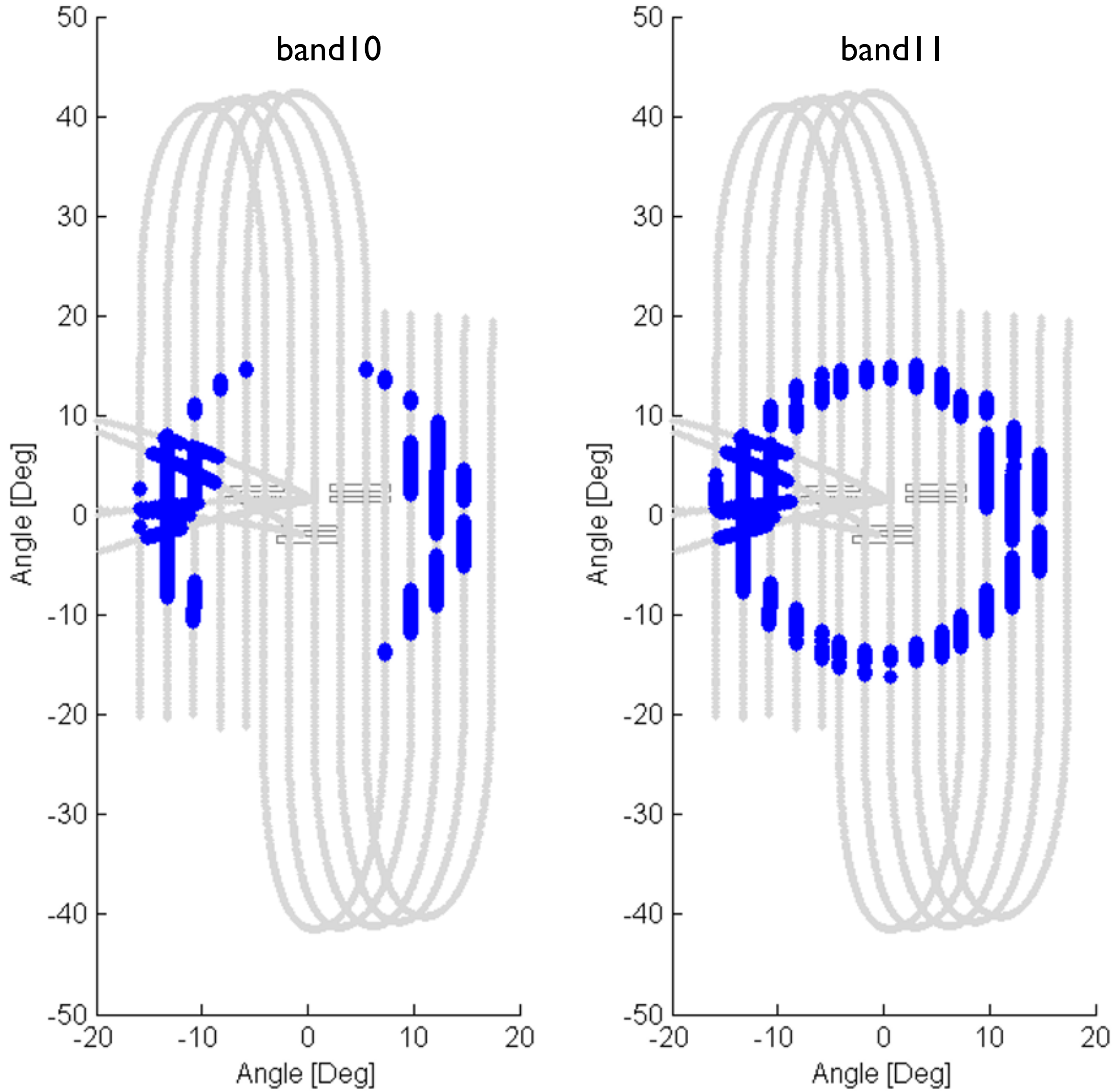
TIRS Stray Light Problem

- Stray light in TIRS seen for out-of-field sources
- Moon scan shows locations for detected signal vs. source position (See extLunarScan03.avi for animated version)
- Need to identify what surface(s) in TIRS are scattering into the field and from what source angles that scattering occurs

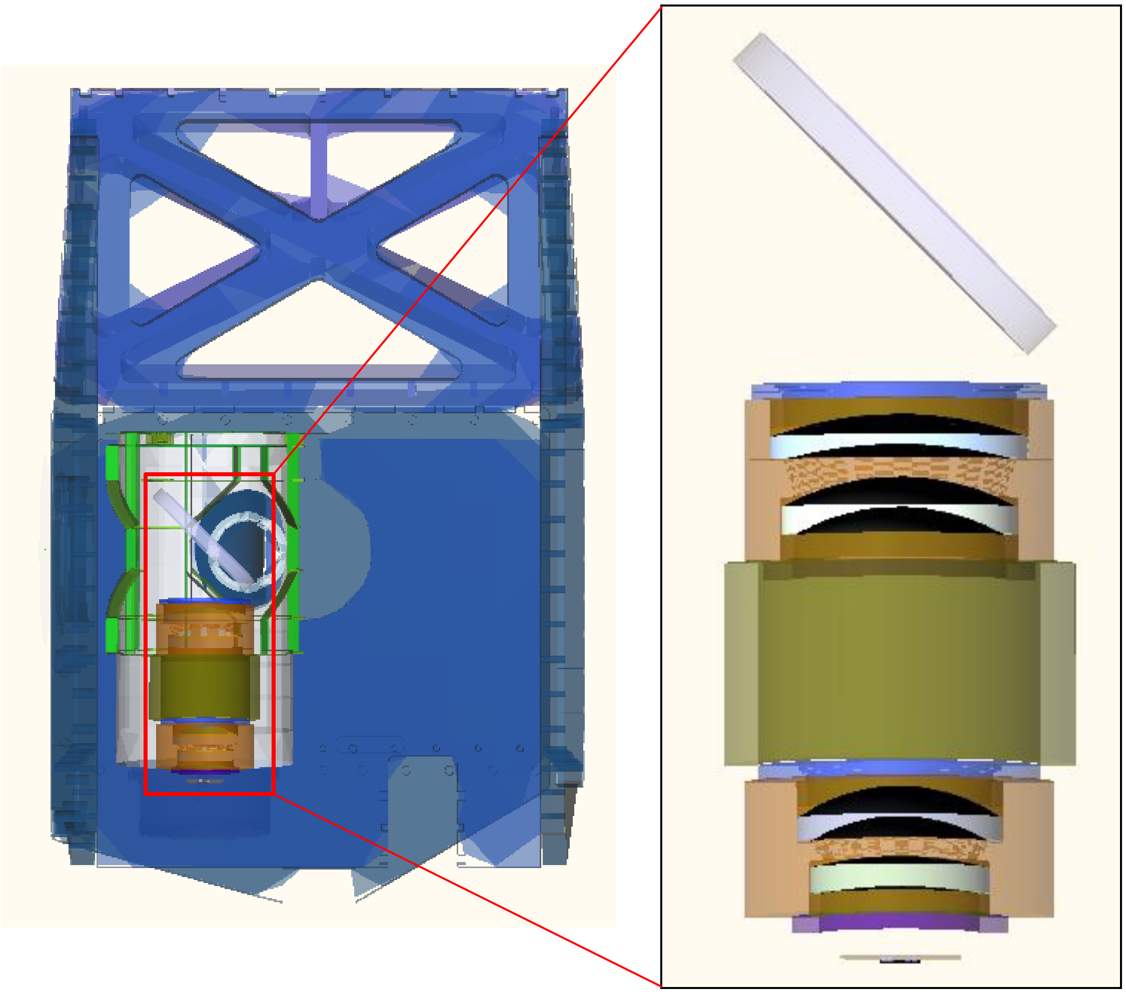


Stray Light

- Can flag lunar locations (blue) in which a ghost appeared <u>anywhere</u> on the detectors
- Provides a sense of how far off-axis the offending signals are originating



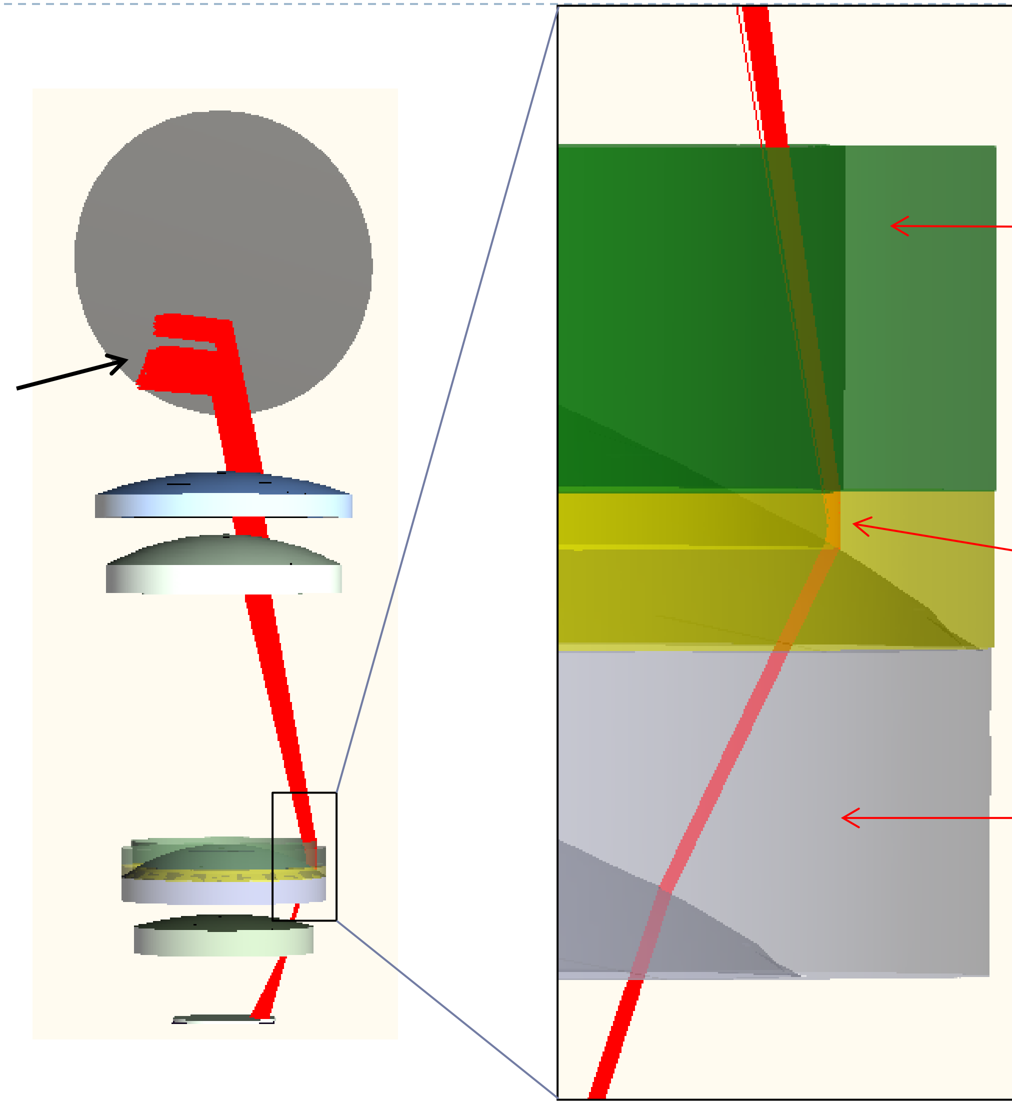
Stray Light Model Built for Analysis



- Optical elements were taken from the cold ZEMAX model (by Eric Mentzell)
- Hardware taken from tom temperature CAD model (by Mike Hersh)
- Telescope hardware modeled natively in FRED software to allow for efficient scaling to operational temperatures

Initial Identification of Scattering Source

Collimated light source from 12 degrees off-axis in azimuth



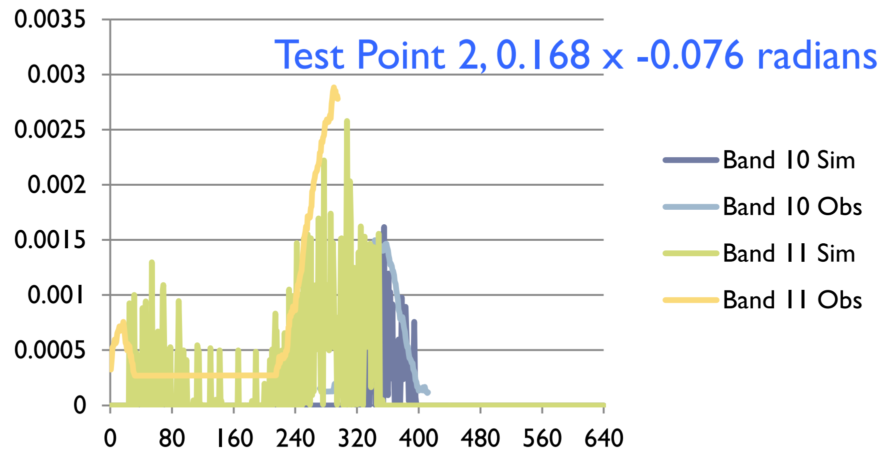
Black anodized Al (little to no reflectance based on measurements done for another program)

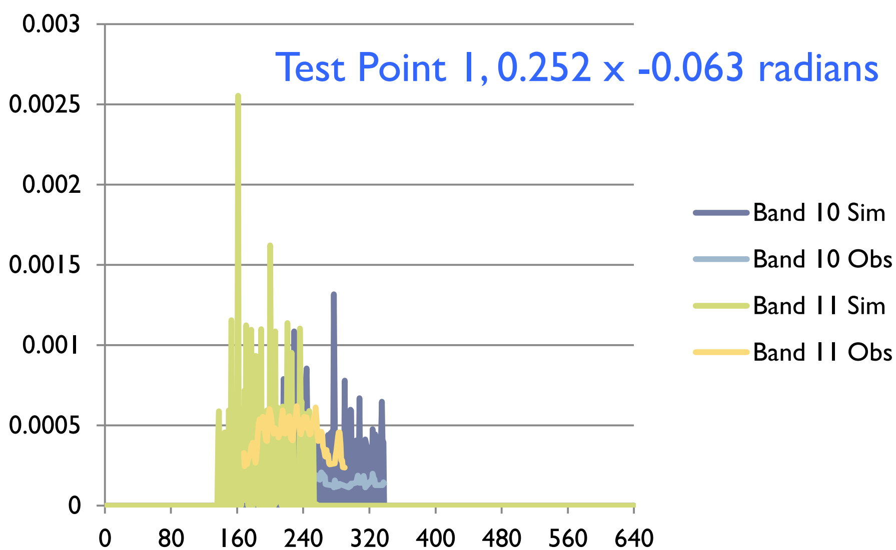
Meldin 7000 ring (100% reflectance)

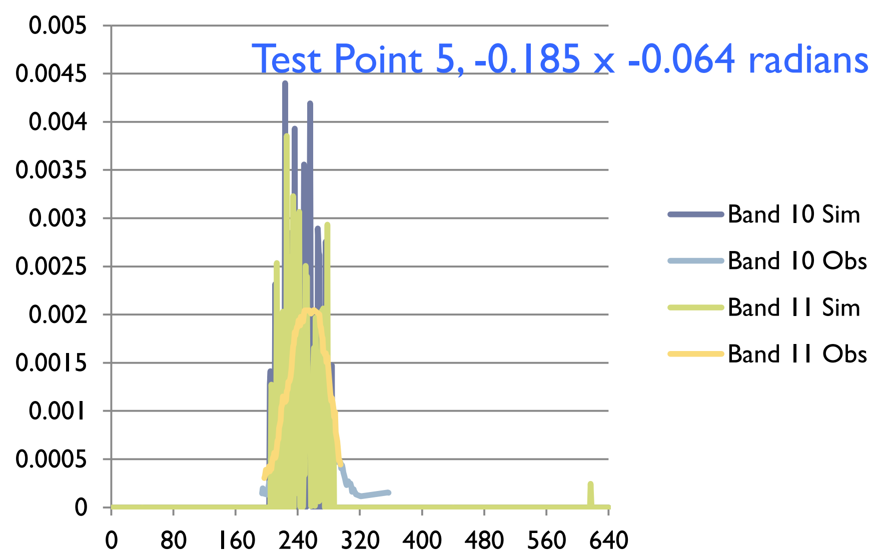
L3 lens

Correlation to Observed Stray Light Signal

- If all internal elements are made absorbing except the Meldin rings that contact the surfaces of the lenses, the simulated (Sim) stray light response agrees well with the observed (Obs)
- Inclusion of scattering from anodized Al indicated signal was too broad when measured scattering properties were used.





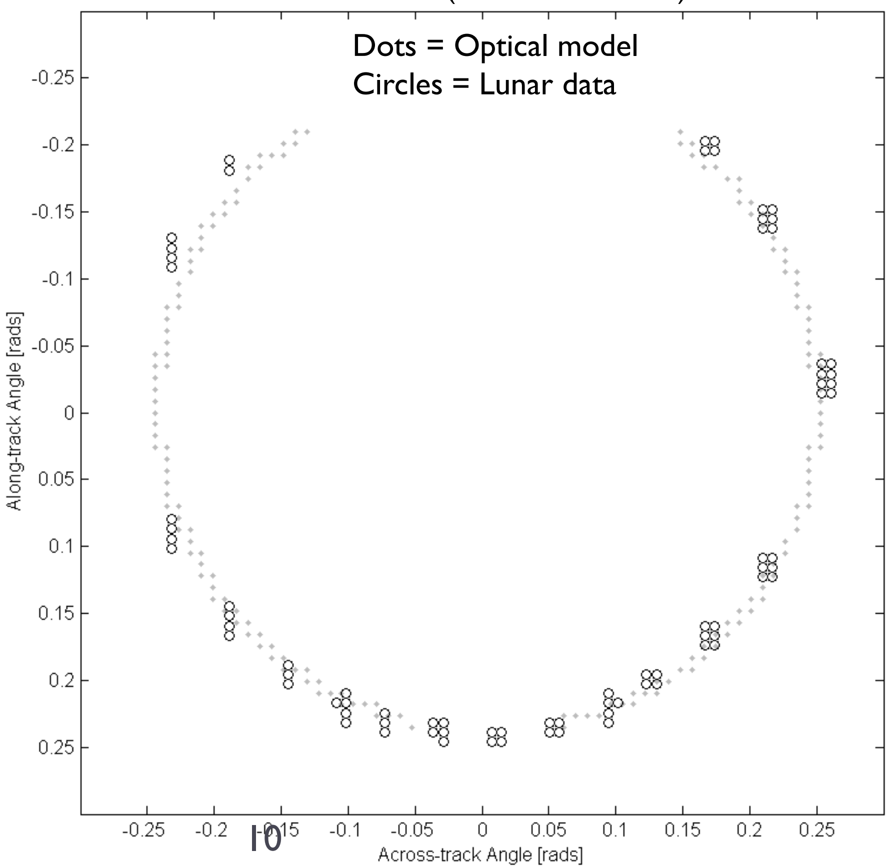


Stray Light Optical Modeling

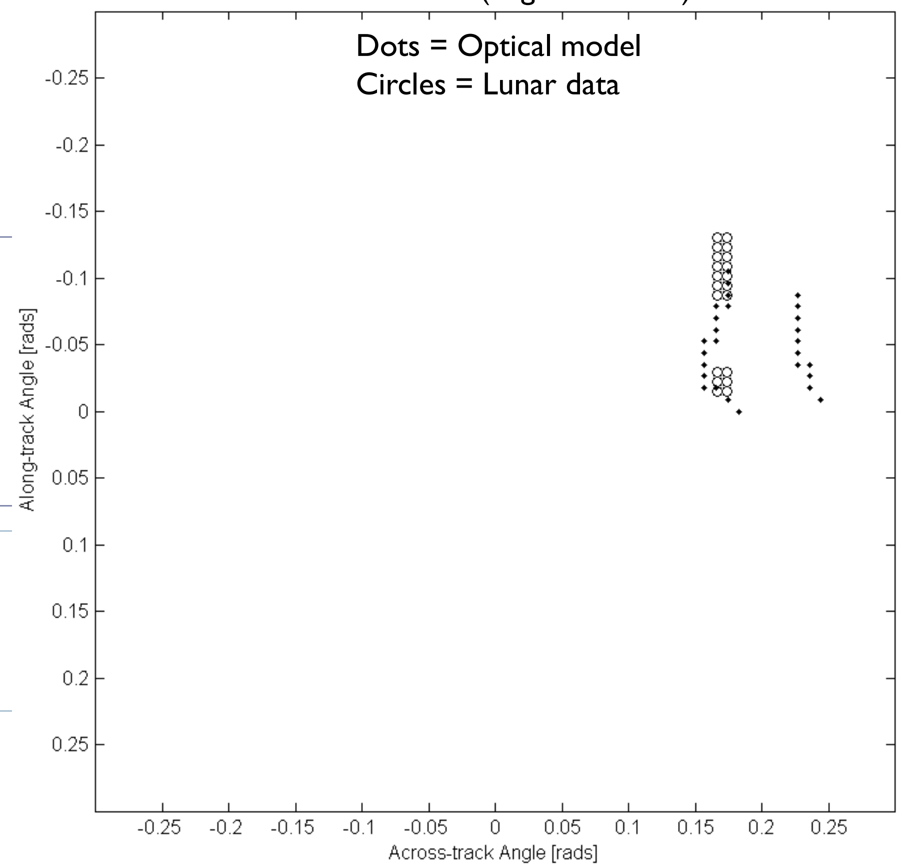
- Do a reverse ray trace at each detector to model PSF of ghosting effect
- Have a complete stray light PSF for every detector (i.e. – no gaps as in the lunar data)
- Some discrepancies, but generally good agreement between model and lunar scans

Comparison of Optical Stray Light Model with Lunar Scan Data for one detector

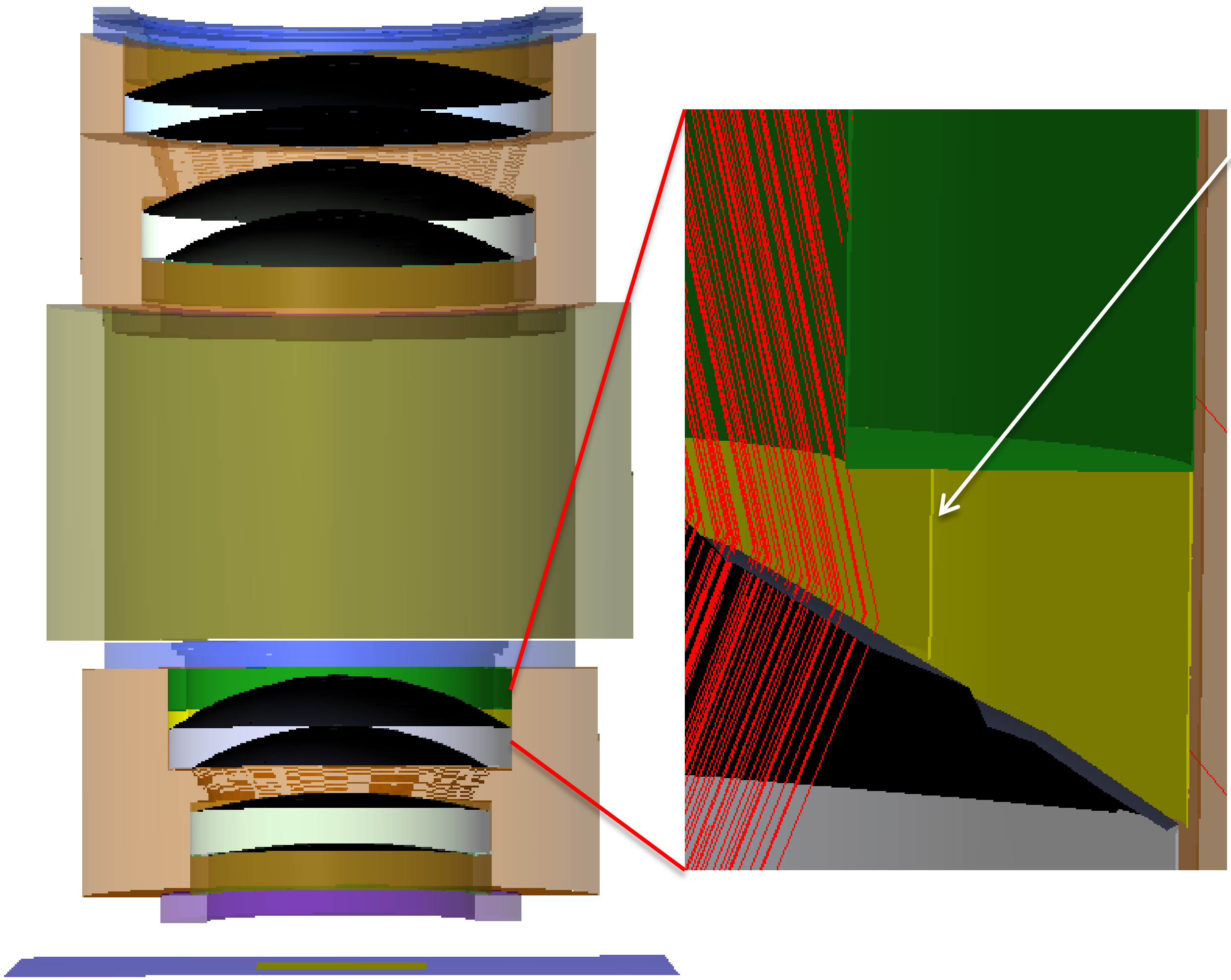
One detector (middle of SCA-C)



One detector (edge of SCA-B)



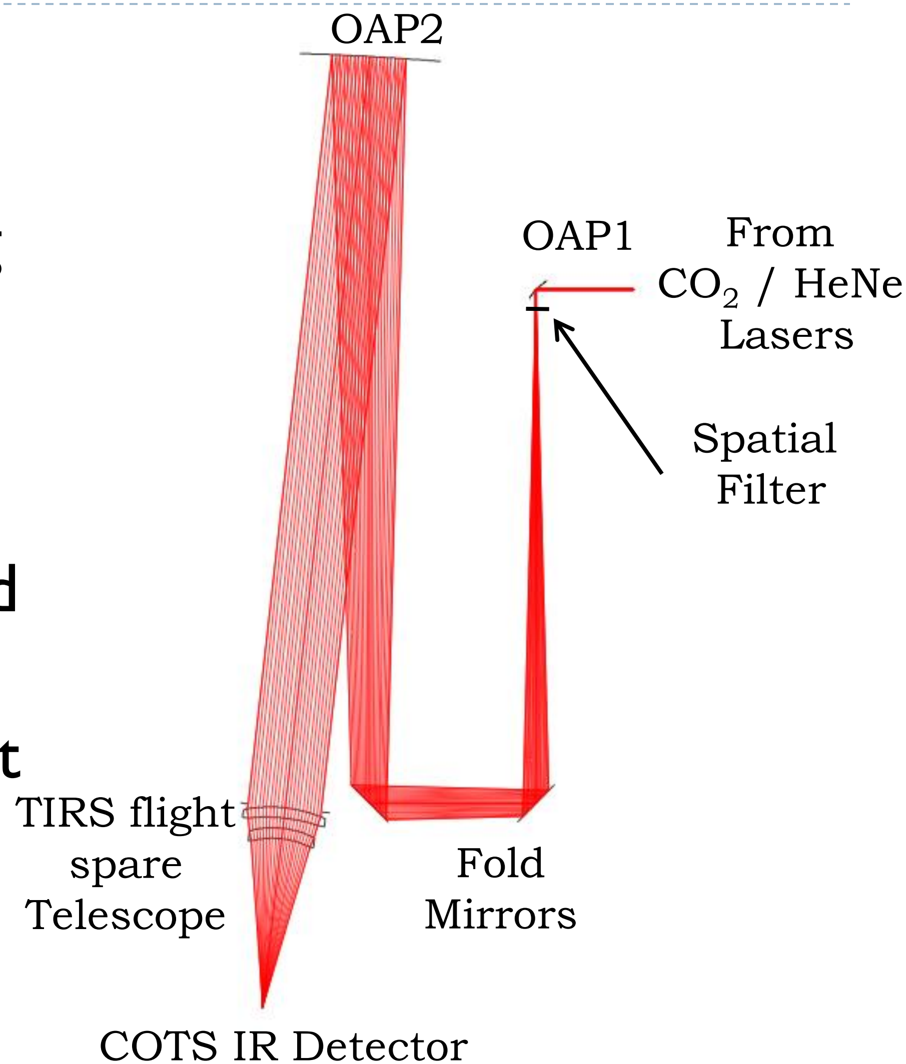
Recommended Solution: Cut back L3 Melding mounting ring 1.5 mm



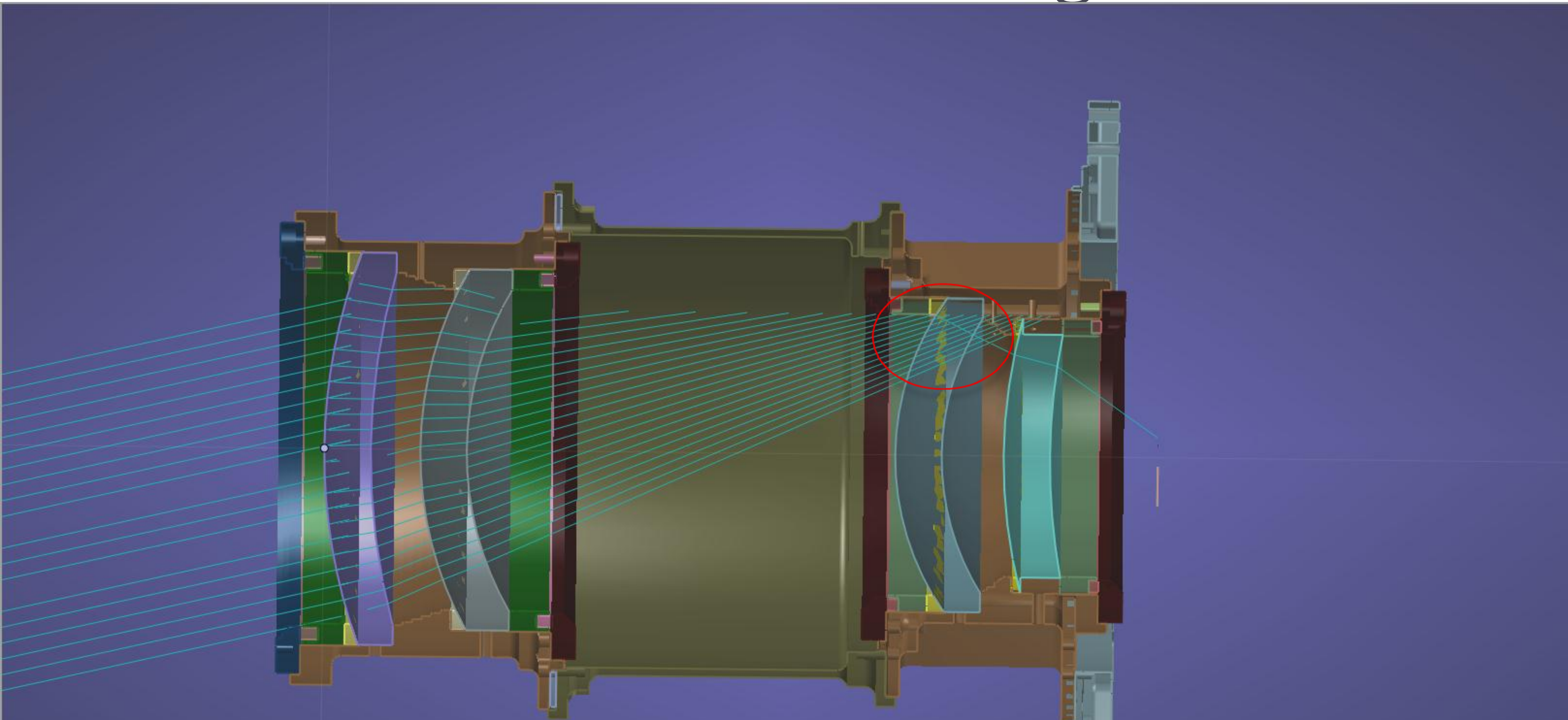
- Reduce wall thickness of mounting ring from 5.5 mm to 4.0 mm
- Possibly changes load path of lens mounting

Subsystem Verification Test

- Rebuild the TIRS wavefront sensing system used originally to assess mounting stress in lens sub-assemblies
- TIRS flight spare telescope mounted on gimbal to point light source from on-axis and off-axis locations to demonstrate stray light effect at the subsystem level
- Verify signal is removed by meldin ring fix

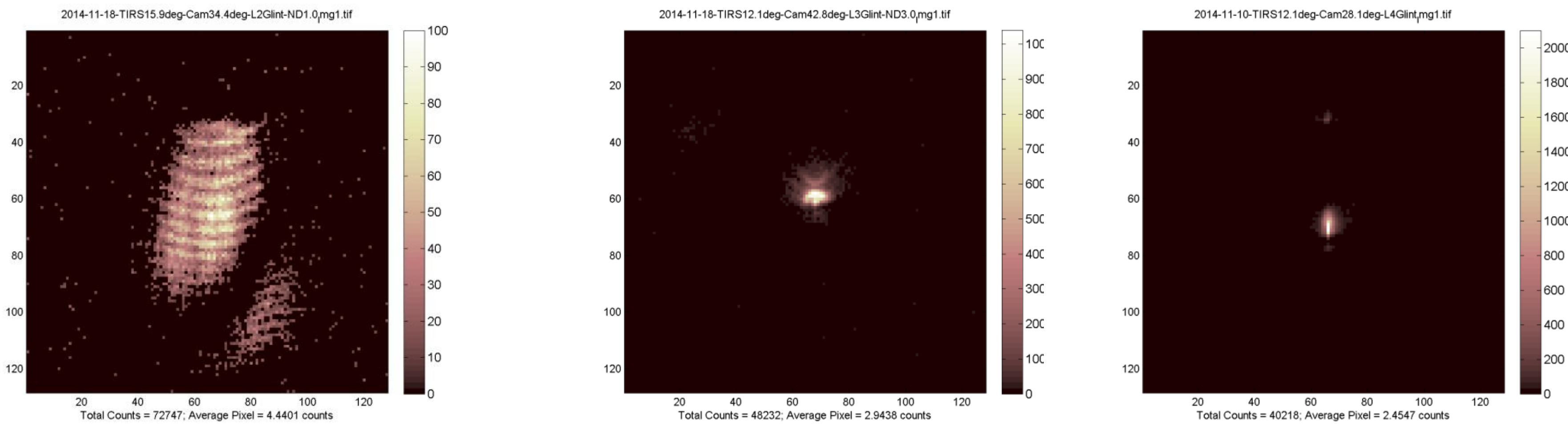


Test for presence of stray light with current lens mount configuration.



Ambient temperature and pressure optical model. External apertures, SSM, 80K shield, filters and detectors all removed.

Glints observed with current lens mount configuration, including “bonus” glints from Lens 2 and 4 mounts.



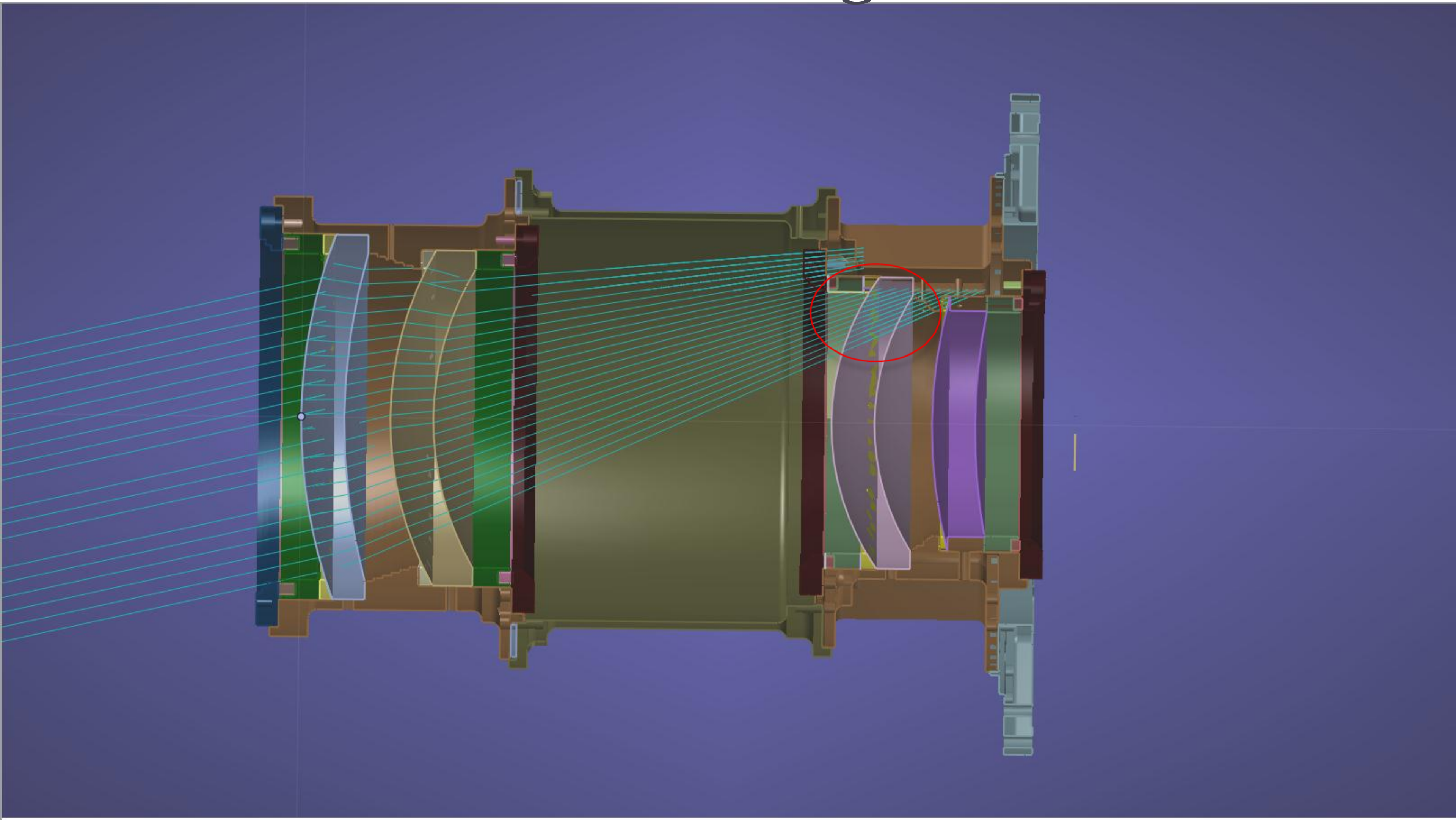
Glints from L3 mount closely follow the optical modelling predictions:

- Used model prediction to set angle of FLIR camera (only capturing part of the spray of stray light in relay lens).
- Lateral position of glint near TIRS focal surface consistent with model
- Range of input angles which produces a glint consistent with model

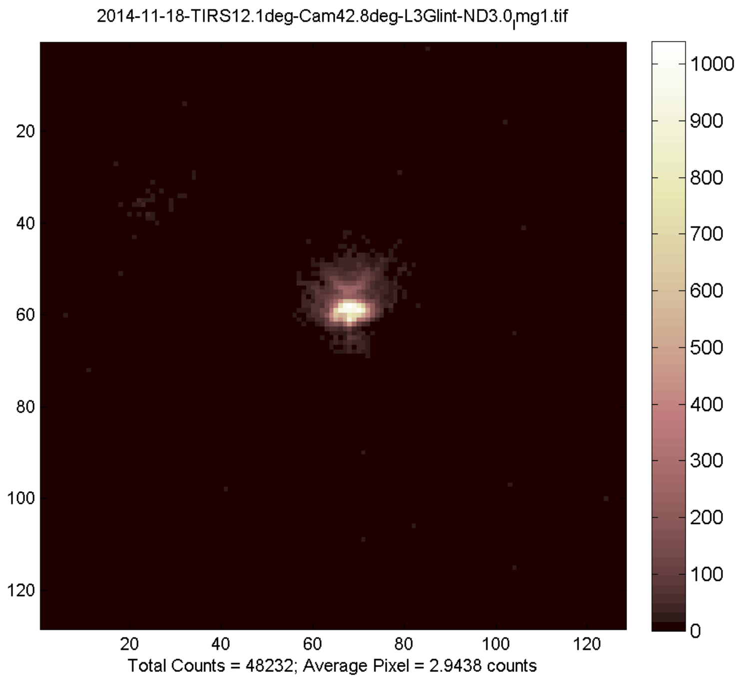
Glints from L2 and L4 mounts also modelled:

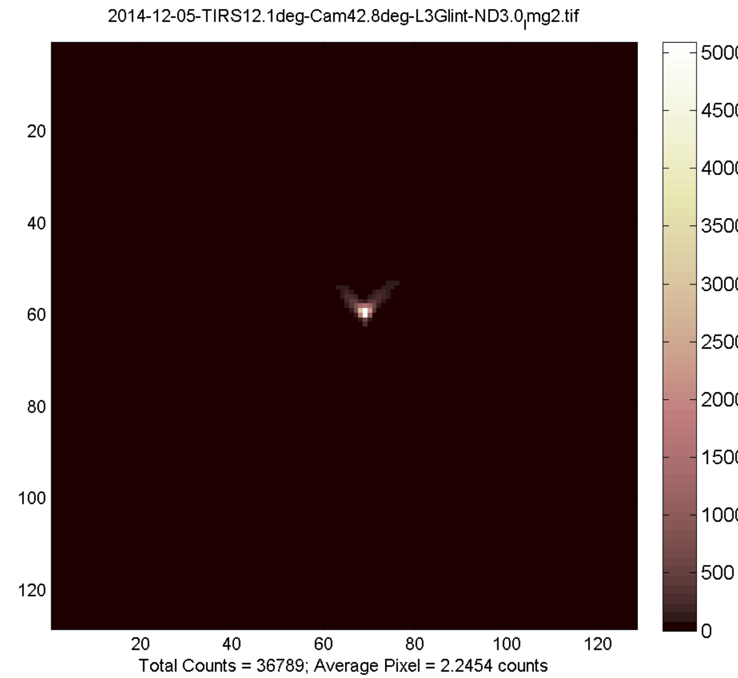
- Lab observations consistent with model
- L2 effect is much weaker (required 100 times more throughput to see)
- On-orbit observations may not have captured these (tbd)

Test for absence of stray light with reduced meldin ring thickness.



L3 glints also observed with modified lens mount: Not expected





Before and after comparison:

- Left the test equipment and alignment fiducials untouched, to get the best repeatability
- Morphology change may be more tied to auto-focus of FLIR camera than anything else
- Average flux reduced about 15% (expected it to be gone)
- L2 and L4 glints still there (as expected)

Probable cause: Reflection from anodized aluminum above L3

- Black anodize on upstream aluminum spacer may not be as black as test data used in model showed

- 15% Flux reduction suggests this (eliminated 2 mm Meldin, but left 12.3 mm aluminum)

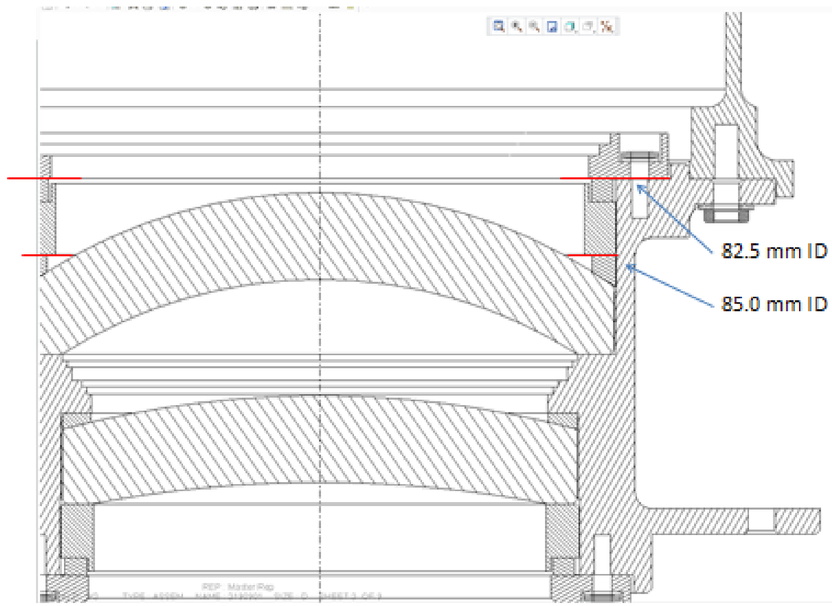
- Originally, Al walls not considered a viable source because the optical model indicated the ghost would be much too broad.
  - But model based on measured properties which showed mainly diffuse scattering
  - Model updated to include more specular reflectance

- Re-do predictions for position and angles of all three glints
  - L3 width now dominated by angular width of lunar target – not much angular difference with or without Al
  - But effect is larger because of increased area

- New mitigation is a vane structure on the aluminum spacer
  - Modify and retest

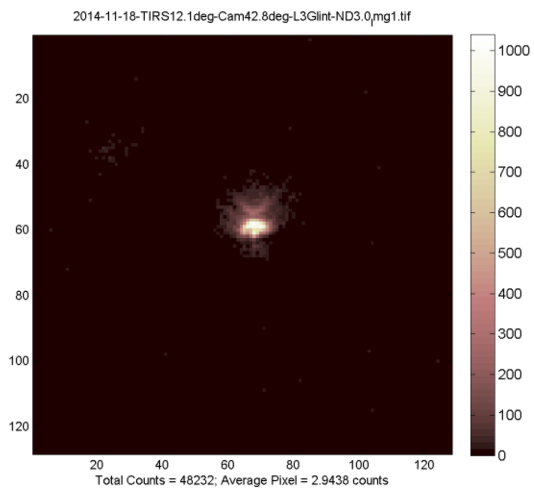
L3 mount modifications:

- To reduce illumination of the Aluminum and Meldin surfaces, and to absorb light reflecting form them, we added two annular baffles. These are thin (0.016”) aluminum sheets, black anodized. One between the conical spacer and the preload spacer, and the other between the wave spring and its clamping ring.
- This baffles will cause a little vignetting for the in-field light, so it’s not necessarily a final fix to the problem. It’s intended to simply confirm that we can baffle the glint.

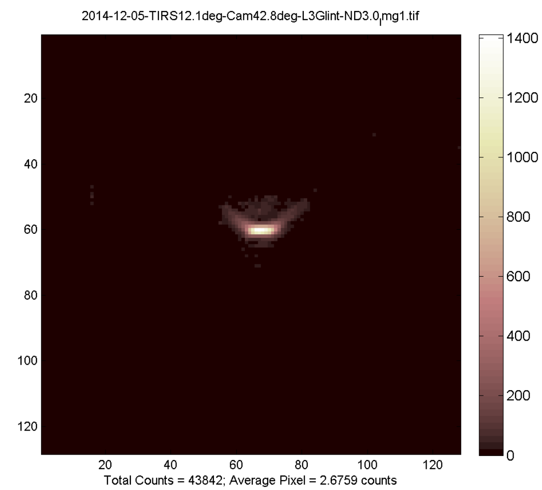


Evolution of L3 Glint, 12.1 deg input

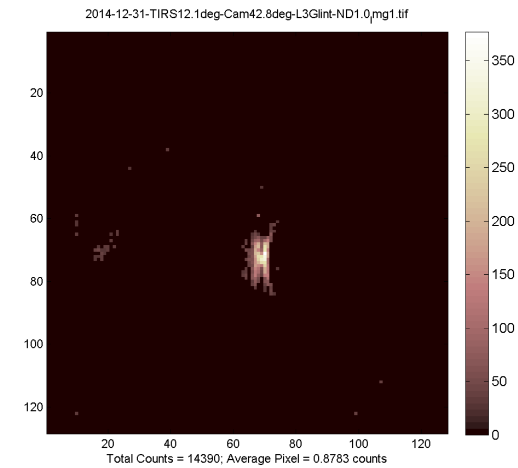
Original (ND3 filter)



Meldin ring mod (ND3 filter)



Added Baffle (ND1 filter)



Meldin ring mod reduced glint 10-15% and changed lateral position.

Adding baffles reduced glint 99.7% from original, and further changed lateral position.

Consistent with optical model, glint reduction is input angle dependent, less reduction at shallow angles, no visible glint above 15.9 degrees.

Summary and Path Forward

- Primary hosting almost certainly caused by lens structure above L3
- Re-doing predictions for position and angles of all three glints
  - Confirmed that the modeling with the black anodized surface being reflective shows only slightly wider artifacts than with just the Meldin reflecting.
- Redoing the per pixel reverse ray traces
  - Initial indications are that they match lunar measurements somewhat better
  - May improve numerical correction
- Develop new mitigation strategy
  - Baffles around aluminum spacer
  - May need to increase mount diameters and possibly lens diameters to avoid vignetting